



Major- and trace-element data from stream-sediment and rock samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska

By Elizabeth A. Bailey¹, Gregory K. Lee², Seth H. Mueller², Bronwen Wang¹, Zoe Ann Brown², and Greg A. Beischer³

¹U.S. Geological Survey, Anchorage, Alaska

²U.S. Geological Survey, Denver, Colorado

³Bristol Bay Native Corporation, Anchorage, Alaska

Open-File Report 2007–1196, version 1.1

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2007
Revised 2010

For product and ordering information:
World Wide Web: <http://www.usgs.gov/pubprod>
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: <http://www.usgs.gov>
Telephone: 1-888-ASK-USGS

Suggested citation:
Bailey, E.A., Lee, G.K., Mueller, S.H., Wang, Bronwen, Brown, Z.A., and Beischer, G.A., 2007, revised 2010, Major-
and trace-element data from stream-sediment and rock samples collected in the Taylor Mountains 1:250,000-scale
quadrangle, Alaska: U.S. Geological Survey Open-File Report 2007-1196, version 1.1,
[<http://pubs.usgs.gov/of/2007/1196/>].

Any use of trade, product, or firm names is for descriptive purposes only and does not imply
endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual
copyright owners to reproduce any copyrighted material contained within this report.

Contents

Abstract.....	1
Introduction	1
Methods of Study	2
Sample Collection.....	2
Sample Preparation	2
Sample Analysis	3
Acknowledgments	4
References Cited.....	4
Tables	6

Figures

Figure 1. Location of the Taylor Mountains 1:250,000-scale quadrangle, Alaska.....	2
Figure 2. Map showing location of stream-sediment and rock samples collected) in the Taylor Mountains 1:250,000-scale quadrangle, Alaska	
.....	http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_fig2.pdf

Tables

Table 1. Major- and trace-element data for 848 stream-sediment samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska	
.....	http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_tables/
Table 2. Major-, rare-earth, and trace-element data for 122 stream-sediment samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska, 2006	
.....	http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_tables/
Table 3. Major-, rare-earth, and trace-element data for 59 rock samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska	
.....	http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_tables/
Table 4. Forty-two elements determined by inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-atomic emission spectrometry (ICP-AES) (four acid digestion) with their upper and lower reporting limits	11
Table 5. Ten elements determined by partial digestion/extraction ICP-AES with their upper and lower reporting limits	12
Table 6. Fifty-five elements determined by ICP-MS and ICP-AES (sodium peroxide sinter) with their upper and lower reporting limits	13

Conversion Factors and Datums

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
Area		
square mile (mi ²)	2.590	square kilometer (km ²)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8.$$

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27). Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929. Altitude, as used in this report, refers to distance above the vertical datum.

Major- and trace-element data from stream-sediment and rock samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska

By Elizabeth A. Bailey, Gregory K. Lee, Seth H. Mueller, Bronwen Wang, Zoe Ann Brown, and Greg A. Beischer

Abstract

In the summers of 2004, 2005, 2006, and 2008 the U.S. Geological Survey conducted a reconnaissance geochemical survey of the drainage basins throughout Taylor Mountains 1:250,000-scale quadrangle, in southwestern Alaska. The purpose of the study was to locate areas of potential interest for ore minerals, provide data that may be used to determine regional-scale element baselines, and provide data for the concurrent U.S. Geological Survey geologic mapping and mineral resource assessment effort. This report provides the stream-sediment sample data for the study.

Introduction

During the summers of 2004, 2005, 2006, and 2008 the U.S. Geological Survey (USGS) conducted a reconnaissance geochemical survey of the drainage basins throughout the Taylor Mountains 1:250,000-scale quadrangle of Alaska. The purpose of this study was to locate areas of potential interest for ore minerals, provide data that may be used to determine regional-scale element baselines, and provide data for the concurrent USGS geologic mapping and mineral resource assessment effort. This report provides the stream-sediment sample data for the study (tables 1-3).

The Taylor Mountains quadrangle, which covers approximately 6,700 mi², is located in southwestern Alaska (fig.1). There are no towns or villages in the quadrangle; access to the study area is limited to air travel. Topographic relief ranges from near sea level to a maximum of about 3,500 ft at Taylor Mountain. Much of the topography of the region consists of low, rolling mountains. Where present, outcrops consist mostly of eroded bedrock and rubble. Boreal forests dominate the region, grading from white spruce, birch, and trembling aspen on uplands to black spruce and tamarack in lowlands. Tall willow, birch, and alder shrub communities are scattered throughout the region (Nowacki and others, 2001).

Several mineral prospects have been noted in the Taylor Mountains quadrangle (Hudson, 2001) and there is small-scale gold placer activity at the Taylor Mountains mine. Additional geochemical data for rock and stream-water samples collected as part of this project are available in Klimasauskas and others, 2006a, Klimasauskas and others, 2006b, Klimasauskas and others, 2007, Wang and others, 2006a, and Wang and others, 2006b. Two additional reports by Wang and others containing analytical data for stream-water samples collected in 2006 and in 2008 are in review.



Figure 1. Location of the Taylor Mountains 1:250,000-scale quadrangle, Alaska.

Methods of Study

Sample Collection

A total of 848 stream-sediment samples were collected (fig. 2; http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_fig2.pdf). Approximately 10 percent of the samples are site duplicates collected for quality control. As part of a Cooperative Research and Development Agreement (CRADA) with the USGS, 115 of these sediment samples were collected by Bristol Bay Native Corporation (BBNC) personnel in 2004. All of the samples consist of fine-grained active alluvium collected primarily from first- or second-order streams as shown on USGS 1:63,360-scale maps. Each sample was composited by collecting sediment increments from several places at the sample site, generally along a 30-ft stretch of the channel.

Fifty nine rock samples were collected. A few of the rock samples are cobbles from the stream where a sediment sample also was collected. Most of the rock samples are rubble-crop or outcrop samples collected as follow-up to stream-sediment or heavy-mineral-concentrate anomalies noted in the analytical data from samples collected in 2004–2006.

Sample Preparation

The stream-sediment samples were air dried and then sieved with an 80-mesh (less than 180-microns) screen. Sediment that passed through the sieve was ground in a vertical pulverizer with ceramic plates to 100 mesh (less than 150 microns) (Peacock and others, 2002). Rock samples are reduced to ½-cm fragments in a jaw crusher. The crushed sample is split, if necessary, and fed into a vertical pulverizer equipped with ceramic plates. The sample is ground to approximately minus 100-mesh (<150 µm) and mixed to insure homogeneity for subsequent analysis (Taylor and Theodorakos, 2002). All samples were prepared by the USGS laboratory in Denver, Colorado.

Sample Analysis

All sediment samples were analyzed for 42 major and trace elements by ICP-AES-MS (inductively coupled plasma-atomic emission spectrometry-mass spectrometry) (http://minerals.cr.usgs.gov/projects/analytical_chem/references.html#M19), a modification of the methods described by Briggs (2002) and Briggs and Meier (2002). This method uses a four acid (hydrochloric, nitric, perchloric, and hydrofluoric) digestion followed by quantification using either ICP-AES or ICP-MS. Although this digestion is considered a “near total” digestion, it will not completely dissolve highly resistant minerals such as zircon, tourmaline, barite, monazite, cassiterite, rutile, and chromite. Data are considered acceptable if recovery for all 42 elements is plus-or-minus 15 percent at 5 times the lower reporting limit and the calculated Relative Standard Deviation (RSD) of duplicate samples is no greater than 15 percent. Upper and lower reporting limits for this method are shown in table 4.

Samples also were analyzed by ICP-AES for 10 trace metals by using a partial digestion and organic extraction technique (http://minerals.cr.usgs.gov/projects/analytical_chem/references.html#M2) a modification of Motooka (1996). This method uses a combination of hydrochloric acid and hydrogen peroxide to dissolve metals not tightly bound in the lattice structure of minerals. The metals are then extracted into an organic solution as metal halides and quantified by ICP-AES. The results of this method may be biased low when compared to other methods of analyses. Data are acceptable if recovery for all 10 elements is plus-or-minus 20 percent on spikes at 5 times the lower reporting limit and the calculated percent RSD of duplicate samples is no greater than 20 percent. Upper and lower reporting limits for this procedure are listed in table 5.

Gold (Au) concentration in samples collected by the USGS in 2004 was determined by atomic absorption spectrophotometry after collection by fire assay. Sample size is 15 grams; the lower reporting limit is 5 ppb (parts per billion) and the upper reporting limit is 10,000 ppb (http://minerals.cr.usgs.gov/projects/analytical_chem/references.html#M7).

Gold, platinum (Pt), and palladium (Pd) concentrations were measured in samples collected in 2004 by the BBNC and in all samples collected in 2005–2008 by the USGS by ICP-MS after separation by fire assay (http://minerals.cr.usgs.gov/projects/analytical_chem/references.html#m20) using a modification of Meier and others (1996). Sample size for this technique is 30 grams. The lower reporting limits are 1 ppb (parts per billion) for Au, 1 ppb for Pt, and 0.5 ppb for Pd. The upper reporting limit for all three elements is 10,000 ppb. Data are considered acceptable if recovery of gold, platinum, and palladium is plus-or-minus 20 percent at five times the lower reporting limit and the calculated percent RSD of duplicate samples is no greater than 20 percent.

Arsenic (As) concentrations were determined by hydride generation-atomic absorption spectrometry (Hageman and others, 2002). The optimum reporting range is 0.2–20 ppm. Concentrations greater than 20 ppm are measured by adding KI-C₆H₈O₆ and then diluting the sample solution. Mercury (Hg) was analyzed by cold vapor-atomic absorption spectrometry and the lower reporting limit is 0.02 ppm (Brown and others, 2002). Samples containing greater than 1.8 ppm Hg were diluted.

Stream-sediment samples collected in 2006 and all of the rock samples were analyzed for 55 major-, rare-earth, and trace-elements by ICP-AES-MS with a sodium peroxide sinter (http://minerals.cr.usgs.gov/projects/analytical_chem/references.html#m22) by using a modification of Meier and Slowik (2002). With this method, samples are decomposed by using a sodium peroxide sinter at 450°C. The resultant cake is leached with water and acidified with

nitric acid. After an addition of tartaric acid, aliquots of the digested samples are aspirated into the ICP-AES and the ICP-MS. The concentrations of the optimal elements from the ICP-AES and ICP-MS are determined. Data are considered acceptable if recovery for all 55 elements is plus-or-minus 15 percent at 5 times the lower reporting limit and the calculated RSD of duplicate samples is no greater than 15 percent. Upper and lower reporting limits for this method are shown in table 6.

Arsenic and Hg determinations were done by the USGS laboratory in Denver, Colorado. All other analyses were completed by a laboratory under contract with the USGS.

Acknowledgments

The authors would like to thank Joe Daugherty and Jamin Klopman for providing camp accommodations, great cooking, and a wealth of local information. Arnie Johnson and Marty Stauber are thanked for providing helicopter support. USGS chemists Dave Detra and Rich O’Leary provided helpful information on analytical methods. The authors also are grateful to Ed Klimasauskas, Ted Moran, and Ellen Hardy of the USGS for their helpful and timely reviews of this manuscript. The authors also thank Keith Labay of the USGS for his careful review of the metadata.

References Cited

- Briggs, P.H., 2002, The determination of forty elements in geological and botanical samples by inductively coupled plasma-atomic emission spectrometry, in Taggart, Jr. J.E. ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002-223-G, version 5.0, p. G1-G18, accessed November 17, 2006, at http://pubs.usgs.gov/of/2002/ofr-02-0223/G01fortyelementICP-AESsolid_M.pdf
- Briggs, P.H., and Meier, A.L., 2002, The determination of forty-two elements in geological materials by inductively coupled plasma – mass spectrometry, in Taggart, Jr. J.E. ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002-223-I, version 5.0, p. I1-I14, accessed November 17, 2006, at http://pubs.usgs.gov/of/2002/ofr-02-0223/I20NAWQAPlus_M.pdf
- Brown, Z.A., O’Leary, R.M., Hageman, P.L., and Crock, J.G., 2002, Mercury in water, geologic, and plant materials by continuous flow-cold vapor-atomic absorption spectrometry, in Taggart, Jr. J.E. ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002-223-M, version 5.0, p. M1-M9, accessed November 17, 2006, at http://pubs.usgs.gov/of/2002/ofr-02-0223/M12HgCV_M.pdf
- Hageman, P.L., Brown, Z.A., and Welsch, E., 2002, Arsenic and selenium by flow injection or continuous flow-hydride generation-atomic absorption spectrophotometry, in Taggart, Jr. J.E. ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002-223-L, version 5.0, p. L1-L7, accessed November 17, 2006, at http://pubs.usgs.gov/of/2002/ofr-02-0223/L06AS24Se_M.pdf

- Hudson, T., 2001, The Alaska resource data file, Taylor Mountains: U.S. Geological Survey Open-File Report 2001-200, 51 p., accessed November 17, 2006, at <http://ardf.wr.usgs.gov/quads/html/TaylorMountains.html/>
- Klimasauskas, E.P., Miller, M.L., Bradley, D.C., Karl, S.M., Baichtal, J.F., and Blodgett, R.B., 2006a, Major- and trace-element concentrations in rock samples collected in 2004 from the Taylor Mountains 1:250,000-scale quadrangle, Alaska: U.S. Geological Survey Open-File Report 2006-1070, 8 p., accessed December 18, 2006, at <http://pubs.usgs.gov/of/2006/1070/>
- Klimasauskas, E.P., Miller, M.L., Bradley, D.C., Bundtzen, T.K., and Hudson, T.L., 2006b, Major- and trace-element concentrations in rock samples collected in 2005 from the Taylor Mountains 1:250,000-scale quadrangle, Alaska: U.S. Geological Survey Open-File Report 2006-1306, 8 p., accessed December 18, 2006, at <http://pubs.usgs.gov/of/2006/1306/>
- Klimasauskas, E.P., Miller, M.L., and Bradley, D.C., 2007, Major- and trace-element concentrations in rock samples collected in 2006 from the Taylor Mountains 1:250,000-scale quadrangle, Alaska: U.S. Geological Survey Open-File Report 2007-1386, 6 p. and database files, <http://pubs.usgs.gov/of/2007/1386/>
- Meier, A.L., Carlson, R.R., Lichte, F.E., and Bullock, J.H., 1996, Platinum group elements by nickel sulfide fire assay separation and inductively coupled plasma-mass spectrometry, in Arbogast, B.F., ed., Analytical methods manual for the Mineral Resource Surveys Program, U.S. Geological Survey: U.S. Geological Survey, Open-File Report 96-525, p. 158-165.
- Meier, A.L. and Slowik, T., 2002, Rare earth elements by inductively coupled plasma-mass spectrometry, in J.E. Taggart, Jr., ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002-223-K, version 5.0, p. K1-K8, accessed February 26, 2007, at http://pubs.usgs.gov/of/2002/ofr-02-0223/K19NewREE_M.pdf
- Motooka, J., 1996, Organometallic halide extraction for 10 elements by inductively coupled plasma-atomic emission spectrometry, in Arbogast, B.F., ed., Analytical methods manual for the Mineral Resource Surveys Program, U.S. Geological Survey: U.S. Geological Survey, Open-File Report 96-525, p. 102-108.
- Nowacki, G., Spencer, P., Fleming, M., Brock, T., and Jorgenson, T., 2001, Ecoregions of Alaska—2001: U.S. Geological Survey Open-File Report 02-297 (map), accessed November 17, 2006, at <http://agdc.usgs.gov/data/usgs/erosafo/ecoreg/ecoreg.html/>.
- Peacock, T.R., Taylor, C., D., and Theodorakos, P.M., 2002, Stream-sediment sample preparation, in Taggart, Jr. J.E. ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 2002-223-A2, version 5.0, p. A2-1-A2-4, accessed November 17, 2006, at http://pubs.usgs.gov/of/2002/ofr-02-0223/A2SedPrep_M.pdf
- Taylor, C.D., and Theodorakos, P.M., 2002, Rock sample preparation, in Taggart, Jr. J.E. ed., Analytical methods for chemical analysis of geologic and other materials, U.S. Geological Survey: U.S. Geological Survey Open-File Report 02-0223-A1, version 5.0, p. A1-1-A1-5, accessed November 17, 2006, at http://pubs.usgs.gov/of/2002/ofr-02-0223/A1RxSampPrep_M.pdf
- Wang, B., Mueller, S., Bailey, E., and Lee, G., 2006a, Aqueous geochemical data from the analysis of stream water samples collected in August 2004—Taylor Mountains 1:250,000 scale quadrangle, Alaska: U.S. Geological Survey Open-File Report 2006-1175, 11 p., accessed December 18, 2006, at <http://pubs.usgs.gov/of/2006/1175/>

- Wang, B., Mueller, S., Stetson, S., Bailey, E., and Lee, G., 2006b, Aqueous geochemical data from the analysis of stream-water samples collected in June and July 2005—Taylor Mountains 1:250,000 scale quadrangle, Alaska: U.S. Geological Survey Open-File Report 2006-1361, 7 p., accessed December 18, 2006, at <http://pubs.usgs.gov/of/2006/1361/>
- Wang, B., Mueller, S., Stetson, S., Bailey, E., and Lee, G., *in review*, Aqueous geochemical data from the analysis of stream-water samples collected in June and July 2006—Taylor Mountains 1:250,000 scale quadrangle, Alaska:
- Wang, B., Owens, V., Bailey, E., and Lee, G., *in review*, Aqueous geochemical data from the analysis of stream-water samples collected in June 2008 and August 2008—Taylor Mountains 1:250,000 scale quadrangle, Alaska:.

Tables

Table 1. Major- and trace-element data for 848 stream-sediment samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska

[Field numbers followed by a “D” are site duplicate samples; field numbers preceded by a “B” indicate samples collected in 2004 by Bristol Bay Native Corporation personnel; TA, Taylor Mountains; INS, insufficient sample for analysis; <, less than the lower reporting limit; Au_FA/AA, gold determined by fire assay/atomic absorption spectrophotometry; FA/ICPMS, Au-Pd-Pt determined by fire assay/ICP-MS; As_HGAAS, arsenic determined by hydride generation-atomic absorption spectrometry; Hg_CVAAS, mercury determined by cold vapor-atomic absorption spectrometry; ICP10_P, 10 elements determined by ICP-AES after partial digestion/extraction; ICP42, 42 elements determined by ICP-AES and ICP-MS after four-acid dissolution; ppb, parts per billion; ppm, parts per million; %, percent]

This table is provided in several file formats at http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_tables/

Table 2. Major-, rare-earth, and trace-element data for 122 stream-sediment samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska, 2006

[Field numbers followed by a “D” are site duplicate samples; TA, Taylor Mountains; ICP55, 55 elements determined by ICP-AES and ICP-MS after sodium peroxide sinter; <, less than the lower reporting limit; ppm, parts per million; %, percent]

This table is provided in several file formats at http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_tables/

Table 3. Major-, rare-earth, and trace-element data for 59 rock samples collected in the Taylor Mountains 1:250,000-scale quadrangle, Alaska.

[Field numbers followed by a “D” are field duplicate samples; TA, Taylor Mountains; <, less than the lower reporting limit; Au_FA/AA, gold determined by fire assay/atomic absorption spectrophotometry; FA/ICPMS, Au-Pd-Pt determined by fire assay/ICP-MS; As_HGAAS, arsenic determined by hydride generation-atomic absorption spectrometry; Hg_CVAAS, mercury determined by cold vapor-atomic absorption spectrometry; ICP10_P, 10 elements determined by ICP-AES after partial digestion/extraction; ICP55, 55 elements determined by ICP-AES and ICP-MS after sodium peroxide sinter; ppb, parts per billion; ppm, parts per million; %, percent]

This table is provided in several file formats at http://pubs.usgs.gov/of/2007/1196/of2007-1196_v1.1_tables/

Table 4. Forty-two elements determined by ICP-MS and ICP-AES (four acid digestion) with their lower and upper reporting limits

[ICP, inductively coupled plasma; MS, mass spectrometry; AES, atomic emission spectrometry; ppm, parts per million; %, percent]

Element	Lower reporting limit	Upper reporting limit	Element	Lower reporting limit	Upper reporting limit
Aluminum, Al	0.01%	15%	Lanthanum, La	0.5 ppm	1,000 ppm
Calcium, Ca	0.01%	15%	Lithium, Li	1 ppm	50,000 ppm
Iron, Fe	0.01%	15%	Manganese, Mn	5 ppm	10,000 ppm
Potassium, K	0.01%	15%	Molybdenum, Mo	0.05 ppm	10,000 ppm
Magnesium, Mg	0.01%	15%	Niobium, Nb	0.1 ppm	1,000 ppm
Sodium, Na	0.01%	15%	Nickel, Ni	0.5 ppm	10,000 ppm
Sulfur, S	0.01 %	5%	Phosphorous, P	50 ppm	10,000 ppm
Titanium, Ti	0.01%	15%	Lead, Pb	0.5 ppm	10,000 ppm
Silver, Ag	1 ppm	10 ppm	Rubidium, Rb	0.2 ppm	10,000 ppm
Arsenic, As	1 ppm	10,000 ppm	Antimony, Sb	0.05 ppm	10,000 ppm
Barium, Ba	5 ppm	10,000 ppm	Scandium, Sc	0.1 ppm	1,000 ppm
Beryllium, Be	0.1 ppm	100 ppm	Tin, Sn	0.1 ppm	1,000 ppm
Bismuth, Bi	0.04 ppm	10,000 ppm	Strontium, Sr	0.5 ppm	10,000 ppm
Cadmium, Cd	0.1 ppm	10,000 ppm	Tellurium, Te	0.1 ppm	500 ppm
Cerium, Ce	0.05 ppm	1,000 ppm	Thallium, Tl	0.1 ppm	10,000 ppm
Cobalt, Co	0.1 ppm	10,000 ppm	Thorium, Th	0.2 ppm	10,000 ppm
Chromium, Cr	1 ppm	10,000 ppm	Uranium, U	0.1 ppm	10,000 ppm
Cesium, Cs	5 ppm	1,000 ppm	Vanadium, V	1 ppm	10,000 ppm
Copper, Cu	0.5 ppm	10,000 ppm	Tungsten, W	0.1 ppm	10,000 ppm
Gallium, Ga	0.05 ppm	500 ppm	Yttrium, Y	0.1 ppm	10,000 ppm
Indium, In	0.02 ppm	500 ppm	Zinc, Zn	1 ppm	10,000 ppm

Table 5. Ten elements determined by partial digestion/extraction ICP-AES with their lower and upper reporting limits

[ICP, inductively coupled plasma; AES, atomic emission spectrometry; values reported in parts per million]

Element	Lower reporting limit	Upper reporting limit	Element	Lower reporting limit	Upper reporting limit
Silver, Ag	0.08	400	Copper, Cu	0.05	500
Arsenic, As	1.0	6,000	Molybdenum, Mo	0.10	900
Gold, Au	0.10	1,500	Lead, Pb	1.0	6,000
Bismuth, Bi	1.0	6,000	Antimony, Sb	1.0	6,000
Cadmium, Cd	0.05	500	Zinc, Zn	0.05	500

Table 6. Fifty-five elements determined by ICP-MS and ICP-AES (sodium peroxide sinter) with their upper and lower reporting limits

[ICP, inductively coupled plasma; MS, mass spectrometry; AES, atomic emission spectrometry; ppm, parts per million; %, percent]

Element	Lower reporting limit	Upper reporting limit	Element	Lower reporting limit	Upper reporting limit
Aluminum, Al	0.01%	25%	Lanthanum, La	0.1 ppm	10,000 ppm
Calcium, Ca	0.01%	35%	Lead, Pb	5 ppm	10,000 ppm
Iron, Fe	0.01%	30%	Lithium, Li	10 ppm	50,000 ppm
Potassium, K	0.01%	25%	Lutetium, Lu	0.05 ppm	1,000 ppm
Magnesium, Mg	0.01%	30%	Molybdenum, Mo	2 ppm	10,000 ppm
Manganese, Mn	10 ppm	10%	Neodymium, Nd	0.1 ppm	10,000 ppm
Phosphorous, P	0.01%	0.25%	Nickel, Ni	5 ppm	10,000 ppm
Titanium, Ti	0.01%	25%	Niobium, Nb	1 ppm	10,000 ppm
Silver, Ag	1 ppm	1,000 ppm	Praesodymium, Pr	0.05 ppm	1,000 ppm
Arsenic, As	30 ppm	10%	Rubidium, Rb	0.2 ppm	10,000 ppm
Barium, Ba	0.5 ppm	10,000 ppm	Antimony, Sb	0.1 ppm	500 ppm
Beryllium, Be	5 ppm	2,500 ppm	Scandium, Sc	5 ppm	50,000 ppm
Bismuth, Bi	0.1 ppm	1,000 ppm	Samarium, Sm	0.1 ppm	1,000 ppm
Cadmium, Cd	0.2 ppm	10,000 ppm	Tin, Sn	1 ppm	10,000 ppm
Cerium, Ce	0.1 ppm	10,000 ppm	Strontium, Sr	0.1 ppm	1,000 ppm
Cesium, Cs	0.1 ppm	10,000 ppm	Tantalum, Ta	0.5 ppm	10,000 ppm
Chromium, Cr	10 ppm	10%	Thallium, Tl	0.5 ppm	1,000 ppm
Cobalt, Co	0.5 ppm	10,000 ppm	Thorium, Th	0.1 ppm	1,000 ppm
Copper, Cu	5 ppm	10,000 ppm	Thulium, Tm	0.05 ppm	1,000 ppm
Dysprosium, Dy	0.05 ppm	0.1%	Tungsten, W	1 ppm	1%
Erbium, Er	0.05 ppm	0.1%	Terbium, Tb	0.05 ppm	0.1 %
Europium, Eu	0.05 ppm	0.1%	Uranium, U	0.05 ppm	0.1%
Gadolinium, Gd	0.05 ppm	0.1%	Vanadium, V	5 ppm	1%
Gallium, Ga	1 ppm	0.1%	Ytterbium, Yb	0.1 ppm	0.1 %
Germanium, Ge	1 ppm	0.1%	Yttrium, Y	0.5 ppm	1%
Hafnium, Hf	1 ppm	1%	Zinc, Zn	5 ppm	1%
Holmium, Ho	0.05 ppm	0.1 %	Zirconium, Zr	0.5 ppm	1%
Indium, In	0.2 ppm	0.1%			